Experimental observation of localisation in a symmetric structure with non-smooth nonlinearities

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Abstract In this work we investigate experimentally the localisation of energy that occurs in a symmetric structure composed of two weakly coupled identical beams impacting against bilateral rigid stoppers. The nonlinear modes of the underlying simplified model display localised solutions bifurcating from the homogeneous out-of-phase mode. In the range of frequencies where in-phase and out-of-phase nonlinear modes can interact, four stable branches are observed both numerically and experimentally, two of which consist of localised vibrating states.

This work aims at investigating, both numerically and experimentally, the existence of localised vibrations in a symmetric structure subject to piecewise-smooth nonlinearities. Energy localisation in two degrees of freedom systems with cubic-type spring nonlinearities has been widely investigated (see e.g. Refs. [1]). Here a minimal model composed of two weakly coupled oscillators subject to bilinear springs is studied (1).

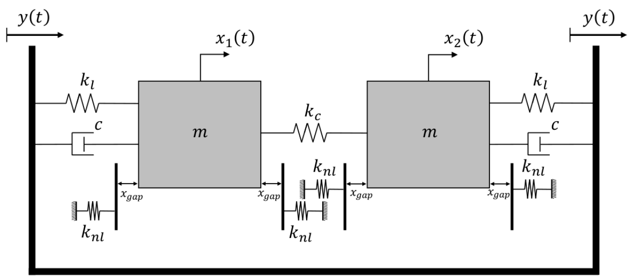

Figure 1: Minimal model of a symmetric piecewise linear system with two degrees of freedom subjected to base displacements.

Nonlinear modal analysis of this system has been performed and the existence of localised states bifurcating from the homogeneous out-of-phase mode is assessed. The out-of-phase solution, stable in the linear regime, loses stability at the grazing point and bifurcates in two localised solution branches. These branches only exist in a restricted range of frequencies that coincides with the range where in-phase and out-of-phase mode coexist. The localised branches then merge back onto the out-of-phase solution branch when the in-phase mode reaches its asymptotic limit frequency. The response of the system to a symmetric excitation also shows stable branches of localised solutions coexisting with the main branch of in-phase vibration.

A test-rig composed of two weakly coupled cantilever beams touching symmetrical stoppers, has been designed to reproduce the localisation phenomenon described above. The piecewise stiffness, which introduces the nonlinear effect in the minimal model of Fig. 1, is obtained by means of impactors placed on each side of each beams at a fixed distance from the beam equilibrium position (cfr Refs. [2]). Two masses attached at the tip of each blade ensure that each beam behaves as a simple oscillator. The base excitation provides the symmetric forcing of both oscillators. Experimental results demonstrated the existence of four stable branches: the lower main branch where both masses vibrates in phase at low amplitude without impacts, the higher main branch where they both touch the stoppers, and two localised branches where they possess an out-of-phase component and either the first or the second beam is impacting and the other is not.

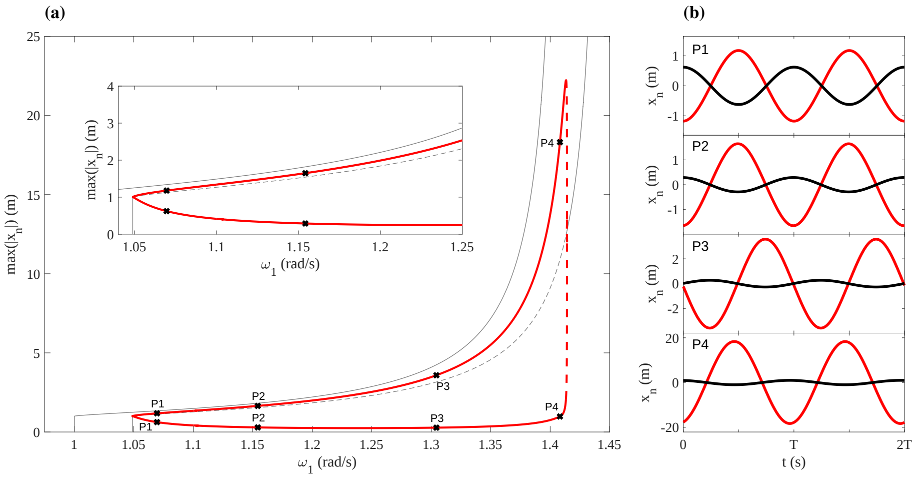

Figure 2: (a) Backbone curves of in-phase ond out-of-phase mode (gray) and localised solutions branch bifurcating at grazing point and merging at limit frequency and (b) displacement of the two masses over time at bifurcated branches

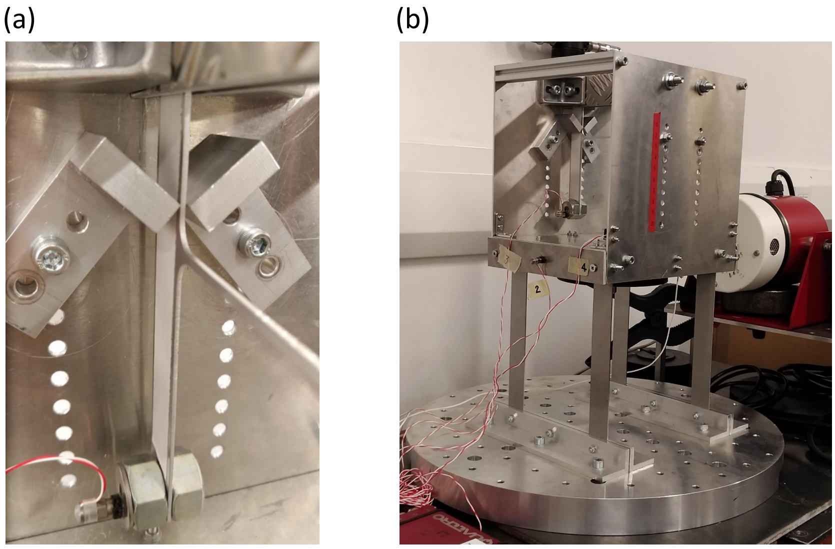

Figure 3: Test rig. Panel (b) shows the platform connected to the shaker, while Panel (a) depicts the stoppers near one of the two beams.

References

[1] T.Ikeda, Y. Harata, and K. Nishimura, *Intrinsic Localized Modes of Harmonic Oscillations in Nonlinear Oscillator Arrays*, Journal of Computational and Nonlinear Dynamics, 8, 041009, 2013.

[2] G. F. S. Rebouas, I. F. Santos and J. J. Thomsen, *Validation of vibro-impact force models by numerical simulation perturbation methods and experiments*, Journal of Sound and Vibration, 413, 291-307, 2018.